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ADDRESS

OF

PROF. H. A. NEWTON,*

VICE PRESIDENT FOR SECTION A.

MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:

I THANK you heartily for the honor you have done me in calling me to preside over this section.

The first of the subjects named as belonging to section A, is mathematics. In the few words I shall say, I wish to ask for that branch the real primacy which has thus in form been given to it. I plead for more study of mathematics by American men of science.

I do not speak of its place in education. Whatever interest we may have in schemes of education, we are not discussing them here. That there has been, and is, a notable lack in the amount of American contributions to mathematics has been so fully shown by my predecessor in this office in a recent number of a leading review, that I need not repeat the story.

It is not, perhaps, to be wondered at that in a new country its flora and fauna, its physical and geological features, should have more attraction at first than the exact sciences. Then, too, there have been in this country large rewards to labor, especially to

* Before the American Association for the Advancement of Science, at Detroit, 1875.

skilled labor. Livings and prizes have enticed men to work where practical results are directly in view, in the applied rather than in the pure mathematics.

But whether these reasons or others have caused it, the unpleasant fact is that the American contributions to the science of quantity have not been large. Three or four volumes, a dozen memoirs, and here and there a fruitful idea having been selected from them, there is left very little that the world will care much to remember. I refer, of course, to additions to our knowledge, not to the orderly arrangement of it. To make first-rate text-books, or manuals, or treatises, is a work of no mean order, and I would not underestimate it. In good mathematical text-books we need not fear comparison with any nation. But so few additions have been made to our knowledge of quantity, that I fear that the idea has been quite general among us that the mathematics is a finished science, or at least a stationary one, and that it has few fertile fields inviting labor, and few untrodden regions to be explored. Hence many bright minds, capable of good work, have acted as though the arithmetic, the algebra, and the mechanics which they studied covered all that is known of the science. Instead of going on in some path out to the bounds of knowledge, as they had perhaps the ability to do, they dug in the beaten highways, and with care planted seed there, hoping for fruit. How much such ill-directed thought has been spent on the theory of numbers, on higher equations, on the theory of the tides, &c., which if rightly expended on some untrodden though humble field of the science, might have added really to human knowledge! And yet hardly any science can show on the whole a more steady progress, year by year, for the last fifty years, or a larger and healthier growth, than the science of quantity. Here too, as in every other science, the larger the field that has been acquired, the longer its boundary line from which laborers may work out into the region beyond.

An individual may wisely neglect one science, in order to work in another. But a nation may not. For the healthy growth of all, each science should be fostered in its due proportion. But the mathematics has such relations with other branches, that neglect of it must work in time wider injury, I believe, to the cause of science, than neglect of any other branch. I will give a few reasons for this belief.

First, I appeal to your experience. Am I wrong in supposing that

each of you has, at one time or another, been arrested by lack of sufficient knowledge of the mathematics in a line of research that seemed promising? Would not each of you join me in urging a young student in almost any branch of science to acquire first of all such a knowledge of geometry, analysis, and mechanics, that the main ideas in them shall ever be familiar to him, and their processes at need be easily recalled? Certainly so often has the regret of a want of such knowledge been expressed to me by successful men of science, that I have little doubt of your answer.

Again, I argue from a natural law of succession of the steps of discovery in the exact sciences. We first see differences in things apparently alike, or likeness in things apparently diverse, or we find a new mode of action, or some new relation supposed to be that of cause and effect, or we discover some other new fact or quality. We frame hypotheses, measure the quantities involved, and discuss by mathematics the relations of those quantities. The proof or disproof of the hypotheses, most frequently depends upon the agreement or discordance of the quantities. To discover the new facts and qualities has sometimes been thought to be higher work than to discuss quantities, and perhaps it is. But at least quantitative analysis follows qualitative. It is after we have learned *what kind* that we begin to ask *how much*. The investigator is lame if he is not prepared to follow up the discovered relations of the quantities.

Again, throughout the sciences of this section, the laws are more and more assuming a mathematical form. In physics I need hardly mention the increasing rule which rational mechanics is acquiring in reducing classes of phenomena to varieties of forces and motions. In chemistry, mathematical laws must govern the combinations of the elements, both in the processes and in the results of chemical union. Though we may not now explain chemical action as one branch of mechanics, yet the mathematical sciences of heat and light cannot be made complete without extending mathematics over large provinces in chemistry. Even in the sciences of section B, the mechanical and other quantitative ideas are gaining a sure place.

The unwisdom of neglecting the mathematics is again seen by considering some of the problems, which appear to be in their nature capable of a mathematical solution. To explain by the accepted laws of rational mechanics all the forces and motions of the

ultimate particles of matter, of inorganic matter even, may very well be beyond the powers of the human mind. But that some of those forces and motions will be explained, even at an early day, seems to be almost certain. So the essential differences in the chemical elements may not be beyond discovery and explanation. Each line in the spectrum has its definite place, and those places are the results of certain laws of structure of the substance that gives the spectrum, and of its consequent action upon the light that comes from or traverses the substance. The time seems near for a Kepler who shall formulate those laws, and for a Principia which shall unite them in their most general mathematical expression. In like manner along the line that in astronomy and physics separates the unknown from the known, there are hundreds of questions whose solution, if they are to be solved at all, must be in part mathematical.

It is with some hesitation that I leave the more familiar ground of this section and speak of the laws of quantity in the other sciences. But there is good reason apparent to even the outside observer, for the belief that the mathematics will in the future (of course, in some cases, the very distant future) have much to do in fields from which it is now very properly shut out. Indirectly, through physics, it has already a foothold in some of them.

Political economy is in its ultimate nature a branch of applied mathematics, and even in its present condition we are entitled to distrust the guidance in it of one who has not clear conceptions of the relations of quantity. In fact, most of the questions in social science seem to have a two-fold character, the one moral, and the other mathematical. In geology how many problems are rising into importance whose solution depends upon mathematics! The geometry of animal and vegetable forms is a subject as yet almost untouched by the mathematician. Yet in the nature of the case each form is the result of definite forces, and similarity and law in the forms represent like properties in the forces producing them.

There is, moreover, a large possible field of applied mathematics in the science that shall explain the relations between the facts of the outside world and the impressions which they make through the organs of sense on the mind. The Greeks solved practically one of its problems when they made the lines of the Parthenon curved that they might appear straight. Another is met by the astronomer when he has to apply to his own observations a personal

equation. When we can explain the correction which one color needs because of its nearness to another color, we may perhaps have more hope of applying to color a unit of measure, and so treating of its quantity. Music has its mathematical basis, and differences in sounds have submitted to analysis and measurement. The physiological theories of vision and hearing must, as they develop by experiment, furnish many problems to be solved by mathematics.

Even in the sciences beyond the domain of this Association there is some evidence of the sovereignty of number and measure. Some of those who have most thoroughly studied the theory of the beautiful, believe that mathematical laws will yet be found to lie at the basis of that theory. The recognition of a more and a less in all our mental powers, impressions, and actions; of a law of obedience to the strongest motive; of an inseparable connection of the greatest good with right moral action; what are these but the indications of the existence of quantitative laws in mental and moral sciences?

That there is a growing conviction that mathematical relations run through all subjects of thought is proved by the increasing use of the word *force*. Men speak of vital forces, mental forces, moral forces, social forces, force of will, force of passions, of affections, of appetites, force of words, force of public opinion, force of conscience, force of character, and so on, through all the range of thought. The word force can hardly be used, even as a metaphor, without implying, to some extent, the idea of a cause and an effect, each possessing the attribute of quantity, and each related quantitatively to the other, though we cannot in our present ignorance measure the one or the other.

Is all this a mere fancy, or a day-dream of the imagination, rather than a sober conception of science fitted to this occasion? If it so seems to you, look at the actual history of one kind of quantity, that of probability. Quantity of probability differs from most kinds of quantities, in that it is an impression on the mind that has no necessary correspondence with the facts of the outside world. It is, to use the mathematical term, a function of finite knowledge, depending for its magnitude entirely upon what we know, or think we know, changing with every accession of knowledge, real or supposed, becoming certainty in the presence of full knowledge, and having no existence where there is no knowledge at all.

This mental impression of the more and the less probable mathematicians learned to measure. Its theory was first applied to simple games of chance, but it has grown in these two hundred years until it is now the firm basis on which rest pecuniary contracts for many thousands of millions of dollars in insurance. It guides and controls, by the method of least squares, approximate measurements in all branches of exact knowledge, and going over into mental science requires logic to be rebuilt from the bottom.

Has the thought arisen in any of your minds that this idea of a possible extension of the science of quantity is derogatory to those other sciences over whose domains it may some time claim a qualified sovereignity—that it puts the good and the beautiful even alongside of the masses which we weigh and the bulks which we measure? Pure mathematics is not a science of matter. It is a mental science, dealing solely with mental conceptions. I am inclined to accept Prof. Peirce's extension and definition of it, that it is the science that draws necessary conclusions. But however we may extend or limit the science, it expresses necessary laws of our thinking, and it is not derogatory therefore to our highest knowledge that it is made subject to it. Moreover, our conceptions of the Creator become higher, as we are led on by our studies to emphasize the words of the Hebrew wise man, "Thou hast put together *all things* in measure, and in number, and in weight."

LIFE-HISTORIES OF THE CRUSTACEA AND INSECTS.

BY A. S. PACKARD, JR.

HAVING left the worms, we come now to a more circumscribed group of articulated animals, in which the jointed body is protected by a more or less dense tegument bearing jointed organs. The barnacles, water fleas, shrimps and crabs are tolerably familiar forms, and therefore we will not pause to discuss the anatomy and classification of these animals, merely premising our account of their development with the following tabular view of the main divisions of the group:

CRUSTACEA.

SUBCLASS I.	SUBCLASS II.
DECAPODA (Lobsters and Crabs).	TRILOBITA.
TETRADECAPODA (Sow Bugs, Beach Fleas).	MEROSTOMATA (King Crab).
NEBALIADÆ (Shrimp-like forms).	
PHYLLOPODA (Leaf-footed Shrimps).	
CLADOCERA (Water-fleas).	
OSTRACODA (Bivalved Water-fleas).	
COPEPODA, including SIPHONOSTOMA.	
CIRRIPEDIA including RHIZOCEPHALA (Barnacles).	

Development of the Barnacles. Before we turn to the life-history of the barnacles, let us look for a moment at the mode of development of those strange parasites, the Rhizocephala, whose larval feet become by a retrograde process of development converted into long irregular root-like extensions which ramify in the body of their host. The animal itself, as it adheres by means of its root-like feet to the under side of the abdomen of the crab on which it lives, would be readily mistaken for a large wart or sausage-like bunch. This shapeless mass is the mature Rhizocephalon, apparently the last term in the series of degradational forms so numerous among the lower Crustacea. This sac-like body is filled with eggs.

After total segmentation the embryo rapidly grows and hatches in an oval form with no distinct head, but with an oval shield-like disc covering the insertion of the three pairs of jointed swimming feet, ending in long bristles which aid in locomotion. This larval Rhizocephalon is comparable with the young of the water-fleas or

copepods, called "Nauplius' (see also Fig. 256), but differs from them in the shield-like expansion of the body, and in the presence of a distinct abdomen ending in a movable caudal fork. But however well developed is the body generally, the young root-barnacles, as we may term them, have no mouth, or so far as known, stomach or intestine, so that after swimming about freely for a few days, they change into the "pupa" state, in which they bear a remote resemblance to the bivalved Ostracodes.

The broad shield of the larva has now become folded together like the covers of a pamphlet, enclosing the body of the pupal root-barnacle. The foremost limbs (to avail ourselves of Fritz Müller's description in his "Facts for Darwin") have become transformed into very peculiar adherent feet (prehensile antennæ of Darwin). From the ends of these feet grow out two filaments which are possibly, as Müller suggests, the "commencements of the future roots." The two following pairs of feet are rejected, six pairs of forked swimming feet have meanwhile grown out on the abdomen, while the tail ends in two short appendages. These pupæ are also mouthless and soon attach themselves by means of their adherent feet to the abdomens of crabs and hermit crabs. The other feet drop off, the filaments grow down into the body of their host, entwining around the intestine or ramifying through the liver. "The only manifestations of life which persist in these *non plus ultras* in the series of retrogressively metamorphosed Crustacea, are powerful contractions of the roots, and an alternate expansion and contraction of the body, in consequence of which water flows into the brood-cavity and is again expelled, through a wide orifice" (Müller).

Such is the ordinary history of a Peltogaster or Sacculina, but Mr. Darwin tells us of another form (*Cryptophialus minutus*) which undergoes the larval state in the egg, hatching in the pupa condition, while another form (a species of Peltogaster?) also leaves the egg in the pupa form.

The barnacle has a somewhat similar life-history. It passes through a stage of total segmentation of the yolk and hatches as a Nauplius-like free-swimming larva, but differs from the Rhizocephalus larva in having a mouth, stomach and intestine, while the body is covered by a triangular shield, the anterior corners of which are prolonged into horns, while the posterior angle extends beyond the tail, the forked abdomen hanging down below this

long spine. The anterior feet (corresponding to the anterior antennæ) are simple, while the two pairs of posterior feet are forked, ending in long bristles.

These well armed creatures swim vigorously about on the surface of the water for a season, moulting several times before assuming the bivalve, pupal condition.

The pupa is almost identical in appearance with the bivalved Sacculina, having no mouth, and with a similar arrangement of limbs, except that no filaments are developed on the anterior pair of limbs, and they possess a pair of compound eyes.

The pupal condition is so much alike in the two groups, as stated by Fritz Müller, that we scarcely see why they should be separated as different groups, as Müller is disposed to regard them, but prefer to consider them as subordinate groups of Cirripedia.

The shield of the bivalved "pupal" barnacle becomes converted into the multivalved barnacle, the solid shell of the latter, as in the true sessile barnacles becoming so unlike the thin bivalves of the pupa, that, as is well known, even Cuvier supposed them to be mollusks, though there was the jointed feelers and the articulate plan of the nervous cord as witnesses of their crustacean affinities. The swimming feet of the larval barnacle become the long slender "cirri" which serve to draw in the food, creating currents setting in towards the mouth. Strange as is this retrograde development, we shall see it paralleled among the fish lice.

To sum up, the barnacles and root-barnacles, which are hermaphrodites, except in one family (Abdominales) pass through the following stages of development:

1. Morula.
2. Nauplius or larva.
3. A bivalved "pupal" stage.
4. Adult retrograde condition.

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Thompson. Zoological Researches and Illustrations I. i. 1828–29.
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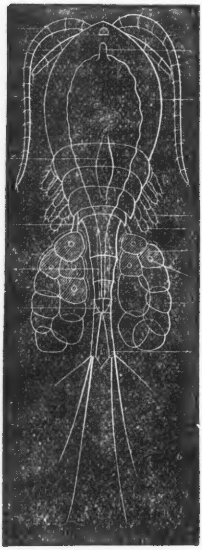
Darwin. A monograph of the subclass Cirripedia. 2 vols. London, 1851–54.
Müller, Fritz. Die Rhizocephalen. (Archiv für Naturgeschichte, 1862.)
Van Beneden, E. Recherches sur l' Embryogénie des Crustacés. III. (Bulletin de l'Acad. Roy. Belgique, 1870.)

Development of the Copepods. As the true Copepods and their allies, the fish-lice or Siphonostomatous Copepods, travel the same

developmental road until the larval stage is completed, the early stages here described apply to the species of both groups. The embryonic development, however, is very simple. The sexes are distinct, and the females (Fig. 235, *Cyclops quadricornis*, after Clark) in many cases swim about as seen in the figure, with a sac of eggs attached to each side of the body.

Fig. 235.



Cyclops.

The embryo in those species of Copepods which have been examined, is formed in the following manner, as observed by E. Van Beneden.

The egg undergoes total segmentation, resulting in a layer of blastodermic cells surrounding the yolk. These cells increase in length on one side, forming the blastodermic disc, or "primitive streak." On the ventral surface of this disc, viz., the side pointing outwards, the three pairs of limbs arise simultaneously, and the Nauplius (or larva) directly hatches, its body more or less oval and rounded.

In this simple condition, with no separation of the body into a head-thorax or abdomen, and with a simple unpaired eye and a labrum, it swims around. The farther transformations can be traced by any one who will take the pains to keep these water-fleas in aquaria.

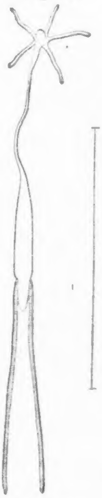
Before the larval Copepod leaves the egg it moults twice; the first is the "blastodermic skin" secreted by the blastodermic cells and exuviated before the limbs bud out. This blastodermic moult, comparable to the serous membrane of Arachnides and the true insects, has been observed by Van Beneden to be the larval membrane of Gammarus, and he has recognized it as surrounding the embryo of Sacculina, Leptomera, Caprella, Nebalia and Crangon.

The second or Nauplian moult takes place after the larval form is attained, but before the embryo hatches. The skin peels off when the appendages are of a certain length and before they are jointed.

At the moment of birth, says Van Beneden, the appendages

are distinctly jointed and provided with simple or branched bristles. The alimentary canal is distinct, so is the eye; and the nerve-ganglion is recognizable, while the blood circulates in the body-cavity.

Fig. 236.



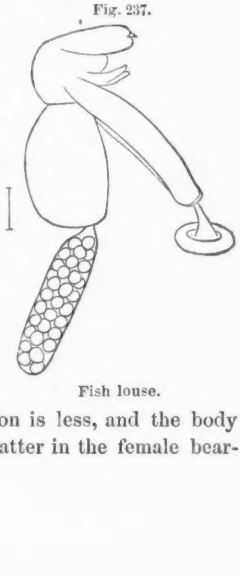
Fish Louse.

While most Copepods leave the egg in this perfected, Nauplius condition, the embryo Anchorella and Hessia, according to the researches of Van Beneden, pass through a Nauplius state in the egg, then three pairs of abdominal feet grow out, and an abdomen, consisting of five well marked segments, is differentiated from the cephalothorax. This stage is called the cyclopian stage by Van Beneden. Now this embryonic stage of the Lernæans, or fish lice, corresponds to the stages undergone by the free swimming young of Cyclops and other Copepods.

The Nauplius of Cyclops in growing to maturity elongates, mouth-appendages, abdominal segments and appendages arise after successive moults, until the adult form is attained.

In the parasitic genera, the larva is either a Nauplius, as in Achtheres and Chondracanthus (in Actheres the young has but two pair of appendages) or, as in Anchorella and others, a cyclops-like being, which after swimming around for awhile fastens itself by its appendages to the gills of some fish. Then begins the race between the organs of vegetative and animal life, the former far outstripping the latter. As in the Lernæa of the cod the appendages grow deep into the flesh of its host like twisted and gnarled roots, while the shapeless sac-like body is, as in the Sacculina, a simple sac filled with eggs. Or the body is still without segments, as in *Lerneonema radiata* (Fig. 236, from Verrill's Report) and ends in two attenuated ovaries; or as in *Actheres Carpenteri*, Fig. 237 (from Hayden's Report), which lives on trout, the deformation is less, and the body is divided into a head and abdomen, the latter in the female bearing two egg-sacs.

Fig. 237.



Fish louse.

To recapitulate the changes undergone by the Copepods in attaining maturity, they pass through the following phases of development:

1. Morula.
2. Nauplius.
3. Cyclopian (in certain genera embryonic) stage.
4. Adult Copepod, in some forms being a degraded more or less amorphous parasitic condition.

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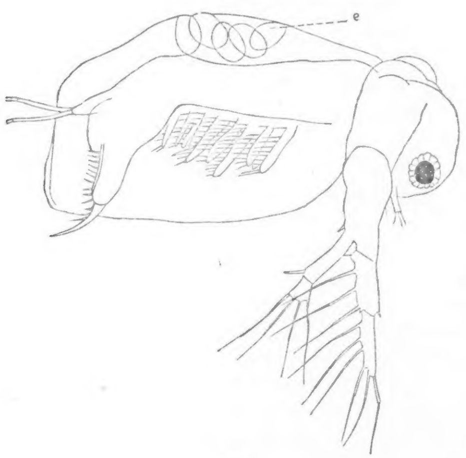
Nordmann. Mikrographische Beiträge zur Naturgeschichte der Wirbellosen Thiere. Berlin, 1832.

Claus. Ueber den Bau und die Entwicklung einiger parasitischer Crustaceen. Cassel, 1858.

Van Beneden, E. Recherches, IV. (Bull. Acad. Bruxelles, 1870.) See also Fritz Müller's Facts for Darwin. Translation. London, 1869.

Development of the Ostracodes and Cladocera. Of the life-history of the bivalved Ostracodes we only know from Claus' studies

Fig. 238.



Sida.

that "the youngest stages are shell-bearing Nauplius forms." It seems evident that these creatures undergo no metamorphosis.

Of the development of the Cladocera, such as the fresh-water Daphnia and Sida (Fig. 238, from Hayden's Survey) we have more certain knowledge. The eggs are borne by the females in

so-called brood-cavities on the back under the shell. The females bring forth two sorts of eggs, *i.e.*, the "summer eggs," which are laid by asexual females, the males not appearing until the autumn, when the females lay the fertilized "winter eggs," which are surrounded by a very tough shell.

Dohrn observed the development of the embryo in the summer eggs. At first the embryo has but three pairs of appendages, representing the antennæ and two pairs of jaws. It is thus comparable with the Nauplius of the Copepods, and thus the Cladocera may be said to pass through a Nauplius stage in the egg.

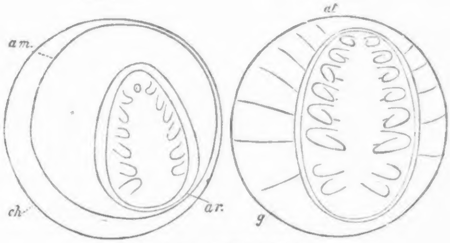
Afterwards more limbs grow out, until finally the embryo is provided with the full number of adult limbs, and hatches in the form of the mature animal, undergoing no farther change of form.

LITERATURE.

Dohrn. Untersuchungen ueber Bau und Entwicklung der Arthropoden. Leipzig, 1870.

Development of the King Crab (Limulus). Here we must turn aside from the true Crustacea to study the development of the king crab, so unlike in its organization to the normal Crustacea, and remarkable for being an ally of the trilobites.

Fig. 239. Fig. 240.



Embryo of King Crab.

Unlike most Crustacea the female king crab buries her eggs in the sand between tide marks, and there leaves them at the mercy of the waves, until the young hatch. The eggs are laid between the end of May and early in July, and the young are from a month to six weeks in hatching.

After fertilization the yolk undergoes partial segmentation, much as in the insects. When the primitive disk is formed (much as in the spiders and certain crabs) the outer layer of blasto-

dermic cells peels off soon after the limbs begin to appear, and this constitutes the serous membrane (Fig. 239, *am*) which is like that of insects.

Then the limbs bud out, the six pairs of cephalic limbs appear at once as in Fig. 239. Soon after the two basal pairs of abdominal leaf-like feet arise, the abdomen becomes separated from the front region of the body, and the segments are indicated as in Fig. 240. A later stage is signalized by the more highly developed dorsal portion of the embryo, an increase in size of the abdomen, and the appearance of nine distinct abdominal segments. The segments of the cephalothorax are now very clearly defined, as also the division between the cephalothorax and abdomen, the

Fig. 241.

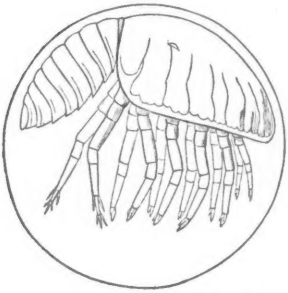


Fig. 242.

King Crab shortly before hatching; trilobitic stage.

latter being now nearly as broad as the cephalothorax, the sides of which are not spread out as in a later stage.

At this stage the egg-shell has split asunder and dropped off, while the serous membrane has increased in size to an unusual extent, several times exceeding its original dimensions and is filled with sea water in which the embryo revolves.

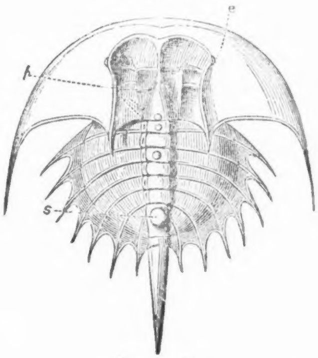
At a little later period the embryo throws off an embryonal skin, the thin pellicle floating about in the egg. Still later in the life of the embryo the claws are developed, an additional rudimentary gill appears, and the abdomen grows broader and larger, with the segments more distinct; the heart also appears, being a pale streak along the middle of the back extending from the front edge of the head to the base of the abdomen.

Just before hatching the head-region spreads out, the abdomen

being a little more than half as wide as the cephalothorax. The two compound eyes and the pair of ocelli on the front edge of the head are quite distinct; the appendages to the gills appear on the two anterior pairs, and the legs are longer.

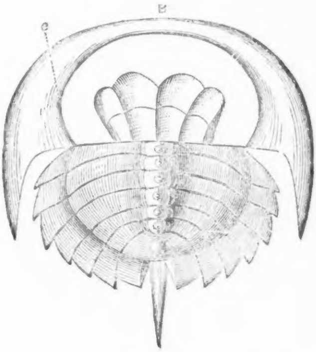
The resemblance to a Trilobite is most remarkable, as seen in Figs. 241 and 242. It now also closely resembles the fossil king crabs of the Carboniferous formation (Fig. 243, *Prestwichia ro-*

Fig. 213.



Prestwichia.

Fig. 244.



Euproöps.

tundatus, 244, *Euproöps Danæ*, from Worthen's Paleontology of Illinois).

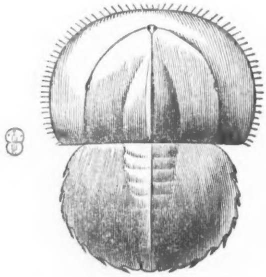
In about six weeks from the time the eggs are laid the embryo hatches. It now differs chiefly from the previous stage in the abdomen being much larger, scarcely less in size than the cephalothorax; in the obliteration of the segments, except where they are faintly indicated on the cardiac region of the abdomen, while the gills are much larger than before. The abdominal spine is very rudimentary; it forms the ninth abdominal segment.

The reader may now compare with our figures of the recently hatched Limulus, that of Barrande's larva of *Trinucleus ornatus* (Fig. 246, natural size and enlarged). One will see at a glance that the young Trilobite, born without any true thoracic segments, and with the head articulated with the abdomen, closely resembles the young Limulus. In Limulus no new segments are added after birth; in the Trilobites the numerous thoracic segments are added during successive moults. The Trilobites thus pass through a

well marked metamorphosis, though by no means so remarkable as that of the Decapods and the Phyllopods.

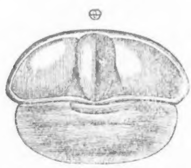
The young swim briskly up and down in the jar, skimming about on their backs, by flapping their gills, not bending their bodies. In a succeeding moult, which occurs between three and four weeks after hatching, the abdomen becomes smaller in proportion to the head, and the abdominal spine is about three times as long as broad. At this and also in the second, or succeeding moult, which occurs about four weeks after the first moult, the

Fig. 245.



Larva of the King Crab.

Fig. 246.



Larva of a Trilobite.

young king crab doubles in size. It is probable that specimens an inch long are about a year old, and it must require several years for them to attain a length of one foot.

The stages of growth, to recapitulate, are as follows: —

1. Peripheral or partial segmentation of the yolk.
2. No true Nauplius stage, but the six legs appear simultaneously.
3. Trilobitic stage.
4. Adult Limulus form attained before hatching.

LITERATURE.

Packard. The Development of Limulus Polyphemus. (Memoirs Boston Society of Natural History. 1872.)

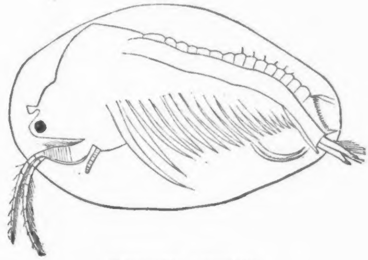
Consult also papers by Lockwood, Dohrn, and E. Van Beneden.

Development of the Phyllopods. We will now return to the true Crustacea, and trace the mode of growth of the leaf-footed forms, beginning with Limnadia (Fig. 548, *L. Agassizii* Packard, in Hayden's Report), a form with whose development we are acquainted.

These shelled crustaceans live in pools which often dry up in summer. The eggs after leaving the oviduct are arranged above the back under the carapace, where they remain for one or two days in midsummer, or for several days during September. The eggs of the European *L. Hermanni* are irregular in form and enclosed in a solid calcareous shell composed of two valves. So thick is the shell that Lereboullet was unable to study the development of the embryo.

The young are hatched in from five to ten days after the expulsion of the eggs from under the carapace. The freshly hatched larva is a nauplius, with the body rather long and with two pairs of appendages bearing bristles, the ante ior pair being forked; there is a single eye in the middle of the head and an enormous labrum. Lereboullet states that the larvæ "have a great resem-

Fig. 247.



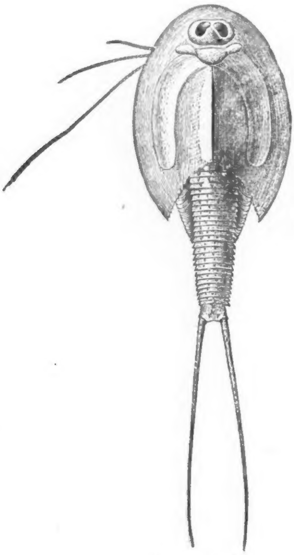
Limnadia Agassizii.

blance with the larvæ of other branchiopod crustacea, among others with those of Branchipus and Artemia. But the larvæ of these two genera have antennæ, which are wanting in the larvæ of Limnadia, while also the larvæ of Artemia have no labrum." About the beginning of the second or third day, the two halves of the carapace begin to grow out from the sides of the base of the abdomen. They finally unite over the back forming a sort of a hinge, and at length enclose the body, with the exception of the head and extremity of the abdomen. When the creature is fully grown, the head and tail are entirely covered by the shells of the carapace. I have found the young of *L. Agassizii* about half a line in length in a pool on Penikese Island early in August. The pool a few days after dried up, and these young met the fate so common to these Phyllopods, but the eggs, protected by their solid calcareous cov-

ering, undoubtedly withstand the desiccation for over one year, and thus the species is preserved.

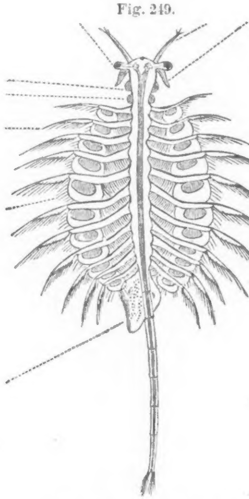
The larval development of *Apus* (Fig. 248, *A. æqualis* Packard, in Hayden's Report) has been studied by Zaddach. We know nothing of the embryology of this animal. I have, however, been able to discover that the blastodermic skin, like that of Limulus, consists of a single layer of moulted cells. Zaddach represents the chorion, or egg-shell, as splitting apart just as in Limulus, and

Fig. 248.



Apus æqualis.

Fig. 249.



Brine Shrimp, Artemia.

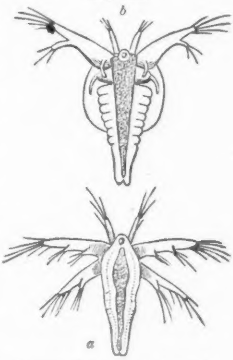
the embryo surrounded by an inner membrane, which is the blastodermic skin.

The young breaks out of its blastodermic skin in the nauplius form, with two pairs of appendages. After a moult a third pair is added and the larva appears as in Fig. 250, *b*. The numerous foliaceous feet, to the number of sixty, are added during subsequent moults.

Of the embryological development of Branchipus and Artemia (Fig. 249, *A. gracilis*, after Verrill) we also know nothing. The

young is hatched in a nauplius condition (Fig. 250, *a*) but with three pairs of limbs. I have observed a similar nauplius-brood in the *Artemia fertilis* of Great Salt Lake. As in Apus, new pairs are added at subsequent moults until the adult form is attained. Siebold has shown that the summer broods of females reproduce by budding, as is probably the case in Limnadia and also Branchipus and Artemia, the males not appearing until towards autumn, though I have found males of *Artemia fertilis* in great abundance in Great Salt Lake late in July. Fig. 251 represents *Branchipus* (Branchinectes) *Coloradensis* (Packard, in Hayden's Report), the female being distinguished by the short clasping antennæ, and the long egg-sac at the base of the abdomen.

Fig. 250.



Larva of Apus; *a*, Artemia.

The Phyllopods, then, with whose embryological development we are not acquainted, after hatching pass through a nauplius stage, and the adult condition is attained after a number of moults.

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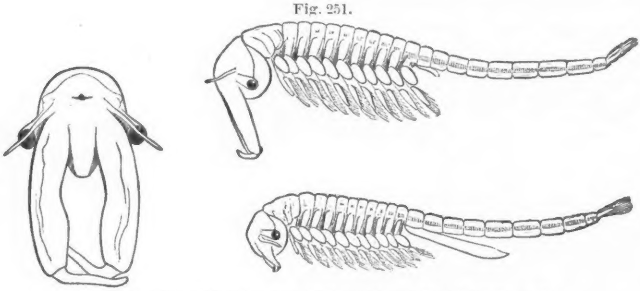
Zaddach. De Apodis cancriformis Anatome et Historia Evolutionis. Bonn. 1841.
Lereboullet. Observations sur la Génération et le Developpement de la Limnadia Hermanni. (Annales des Sc. Nat., 1866.)

Development of Nebalia. A great degree of interest attaches to the life-history of this animal, which is not uncommon in deep water off our coast. It is a relict of a group still older than the king crab, being represented in the primordial rocks by Hymenocaris, and in lower Silurian strata by Discinocaris and Peltocaris, and in the upper Silurian by Ceratiocaris and other forms, gigantic in size (some of them being about seven inches long) compared with the recent Nebalia, which is about half an inch in length. Nebalia is regarded by Metschnikoff as a Decapod; it may be regarded at least as a connecting link between the Phyllopods and Decapods, and as a prophetic type preceding, in paleozoic time, the introduction of the mesozoic Decapods.

Judging by the plates of Metschnikoff's memoir, for the text is written in Russian (a sealed language to us), the early develop-

ment of Nebalia is apparently identical with that of Oniscus, as studied by Bobretzky, and probably all the Tetradecapods, and also with that of perhaps the majority of the Decapods. As in Oniscus the segmentation is partial, the blastodermic cells arising from the subdivision of a polar cell, finally forming a blastodermic disk consisting of a few large cells. At first but three pairs of appendages arise; these corresponding to the two pairs of antennæ and the third to the mandibles. At this period the abdo-

Fig. 251.



Branchinectes Coloradensis and front view of head of the male.

men is distinct from the cephalothorax, but on the whole the embryo may be said to pass through a nauplius stage.

Then the two pairs of maxillæ and two pairs of feet arise simultaneously, the abdomen increases considerably in length, when the ten other pairs of foliaceous feet spring forth. Meanwhile the bivalved carapace grows out from behind the eyes, covering the cephalothorax and base of the abdomen. The young hatches soon after the shield is developed and the further changes are but slight.

The Nebalia, then, in brief, passes through the following stages:

1. Partial segmentation of the yolk.
2. Nauplius stage (in the egg).
3. Larval form like the adult; with no metamorphosis.

LITERATURE.

Metschnikoff. The History of the Development of Nebalia. (In Russian.) St. Petersburg, 1868.

Development of the Tetradecapods. Much good work has been done since the days of Rathke, on the mode of growth of the fresh

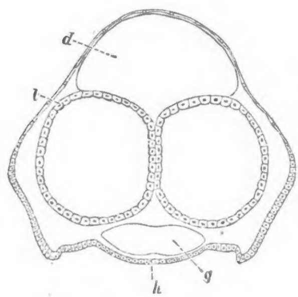
and salt water sow-bugs, etc. (Isopods), and the beach fleas (Amphipods). The development of the *Asellus aquaticus* of Europe has been studied by E. Van Beneden. He found that the segmentation of the yolk is partial; that after a blastodermic moult the two pairs of antennæ are formed before the mandibles and maxillæ, the embryo passing through a Nauplius phase. At this time the embryo moults again. Like all Tetradecapods the young hatch in the form of the adult, there being no metamorphosis. Perhaps the most careful study of the embryology of the higher crustacea, with the improved means of examination instituted mainly by Kowalevsky, is that of *Oniscus murarius*, a sow-bug, by Dr. N. Bobretzky, a student of the eminent Russian zoologist. The following is an abstract of his paper. The egg is provided with a chorion and yolk skin. The first change after fertilization is the origin of the formative or original blastodermic cells, which arise at one pole of the egg. As a result of the self-division of the single primitive blastodermic cell, there arises a disk corresponding to the primitive streak of other articulates, consisting of a single layer of large spheres of segmentation. It thus appears that the segmentation is partial.

Before one-half of the surface of the egg is covered, the middle and inner germ-layers are indicated by a mass of cells in the concavity of the outer layer, resulting from the division of some cells of the outer layer. This primitive mass is the first indication of the innermost (third) and middle layers. The third or inner layer consists of large cells mingled with the yolk cells, among which they press. (He finds this to be the case also in Crangon and Palæmon.) There are, then, three germ-layers as in the vertebrates.

The primitive disk, or streak, then forms by the cells of the outer layer assuming a cylindrical form. The first indication of the intestine is an invagination of the hinder end of the primitive band. A larval skin, like that of Asellus and other crustacea, arises when the first traces of the appendages appear. Bobretzky finds that, contrary to Kowalevsky's opinion, the inner germ-layer in the crustacea agrees with that of vertebrates. Soon after the limbs grow out, a cross-section shows that it is due to a bulging out of the outer germ-layer, the cavity being filled with cells of the middle layer. Now appear the first indications of the liver, a layer of large cells forming the liver sac. After the appendages

appear, the nervous cord arises as a thickening of the outer layer on the ventral side of the primitive band, and consists of three or four layers of roundish cells. Fig. 252 (this and Fig. 253, after Bobretzky) is a transverse section of an embryo in nearly the same stage as the embryo Amphipod (Fig. 254); *d* indicates the intestine, and *l*, the two lobes of the liver; *g*, a transverse section of the nervous cord, and *h*, the walls of the body (hypodermal layer). The opening of the liver into the intestine is shown in another section made and drawn by Bobretzky.

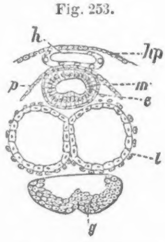
Fig. 252.



Section of Embryo Sow-bug.

One of the most difficult problems to solve in the embryology of the Arthropods is the origin of the large intestine. It is known that it arises out of the yolk sac, but how and where it takes its origin remained without an answer. "After I had ascertained," says Bobretzky, "in the Astacus and Palæmon the peculiar relation of the intestino-glandular cells to the yolk, I could, in these Crustacea, follow step by step the origin of the epithelium constituting the walls of the large intestine. This epithelium first appears in the liver sac." He found the same mode of origin in Oniscus. The next step is the disappearance of the yolk, while the large intestine is fully formed, but there is as yet no communication with the stomach, there being a double wall of cells shutting off the large intestine.

Fig. 253.

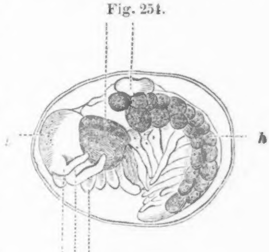


Section of advanced embryo Sow-bug.

The heart is the last to be formed; it arises from the middle layer, though Bobretzky was unable to study its early development. Fig. 253 is a transverse section of the body showing the viscera; *h*, indicates the heart; *hp*, hypodermal layer, or body wall; *m*, muscular wall of the intestine; *e*, epithelial lining of the intestine; *p*, the dividing wall between the heart and the intestine; *l*, the two lobes of the liver; *g*, ganglion, the clear space being filled with the fine granular substance of the ganglion. Nothing

has been said of the development of the external parts. The two antennæ in Oniscus and Asellus are the first to bud out (Nauplius stage) and then the remaining appendages of the head and thorax appear together, and subsequently the abdominal feet are formed. The abdomen is curved up and backwards, while in the Amphipods it is bent beneath the body, as in Fig. 254, and this is really, as Fritz Müller observes, the only important difference between the embryos, at an early stage, of the two groups. The embryo Isopod at the time of hatching closely resembles the adult, there being no metamorphosis.

Fig. 254.



Embryo of an Amphipod. *h*, head; *a'a'*, antennæ; *y*, yolk; *m*, mouth-parts.

The development of the Amphipods or beach fleas, is nearly identical with that of the Isopods. The eggs of certain species undergo total segmentation, while those of other species of the same genus (Gammarus) partially segment, as in the spiders, and in a less degree the insects, showing the slight importance to be attached to this matter, and that Hæckel's term *Morula* when used for the total segmentation of Crustacea is of little significance, how much it may be in the lower animals. It should be borne in mind that it has been used in the present work mainly as a convenient term to avoid circumlocution.

Fig. 254, after Müller, represents the embryo of a Corophium, magnified ninety diameters, in which all the limbs are developed.

Summary of changes:—

1. Segmentation of the yolk partial, or total (Morula).
2. Nauplius state in the egg.
3. Larva hatching in the form of the adult with the full number of feet; no metamorphosis.

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——. Zur Morphologie, Reisebemerkungen aus Taurien. Leipzig, 1837.

Rathke. Untersuchungen ueber die Bildung und Entwickelung der Wasser-Assel (Asellus aquaticus). Leipzig, 1832.

Bobretzky. Zur Embryologie des Oniscus murarius. (Siebold and Kölliker's Zeitschrift. 1874.)

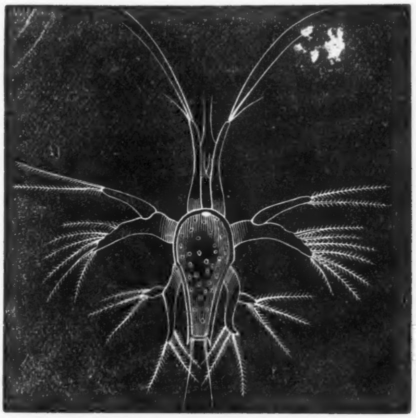
Development of the Decapods. When we come to the stalk-eyed Crustacea, such as the shrimps and crabs, we are introduced to a group of animals in which there is a most striking metamorphosis, as first shown by Thompson. The life-history of a Decapod is full of interest and significance, as the phases which some present from the larval stage up are as varied and astonishing as the biography of any animal known. In the group as a whole, we have species in which the metamorphoses are performed in great detail and complexity of form, the animal shifting its garb as if an actor with many parts to perform in the drama of life, while in its co-species these phases may be mostly suppressed, and the few it does undergo, rapidly assumed and discarded within the narrow compass of the egg-shell.

One Decapod, the shrimp Penæus, studied by Fritz Müller, on the coast of Brazil, is an exception to all other stalk-eyed Crustacea in hatching as a true nauplius, and then by a complicated series of metamorphoses assuming the zoëa and finally adult life. On the other hand, there is the common-lobster, or fresh water craw fish, whose free nauplius and zoëa stages are suppressed, undergone in the egg, and which hatches in nearly or quite a similar form to the fully grown animal. Between these stages there are all grades in other Crustacea.

As regards the development of the embryo, there is in those species which undergo a metamorphosis, a quite similar mode. The yolk so far as known (Scyllarus, Astacus, etc.) undergoes partial segmentation: no case of a total division is as yet known. After the formation of a short round primitive streak, or band, the limbs arise. In several cases observed by Dohrn, the three anterior pairs of limbs, namely, the two antennæ and the mandibles were developed simultaneously and before the others appear. The embryo may with truth, then, as Dohrn states, be said to pass through a nauplius condition in the egg, as much as a mammal passes through a fish-like stage. He observed this nauplius-stage in the embryo of Scyllarus, Pandalus and Galathea. I have observed it in *Lupa hastata* at Charleston, S. C., and *Libinia canaliculata*. It is not improbable that most crabs pass through a nauplius state. As if in proof of the supposition held that this is a true nauplius *in embryo*, we have the fortunate discovery, by Fritz Müller, of the fact that a Brazilian shrimp (Penæus, allied to *P. setiferus* of Florida) leaves the egg "with an unsegmented ovate body, a median frontal eye, and three pairs of natatory feet,

of which the anterior are simple, and the other two biramose; in fact, in the larval form, so common among the lower Crustacea, to which O. F. Müller gave the name of *Nauplius*. No trace of a carapace! No trace of the paired eyes! No trace of masticating organs near the mouth which is overarched by a helmet-like hood!" Let us, with Müller, follow the subsequent history of this young shrimp. After passing through the nauplius condition (Fig. 255) it acquires several pairs of appendages (maxillæ and maxillipedes), but as yet no true legs. It is now a typical zoëa (Fig. 256) having two compound eyes, a carapace and a jointed body. The next

Fig. 255.



Nauplius, or larva, of a Shrimp.

important step is the appearance of the five pairs of thoracic feet, and soon the mature form of the prawn is attained.

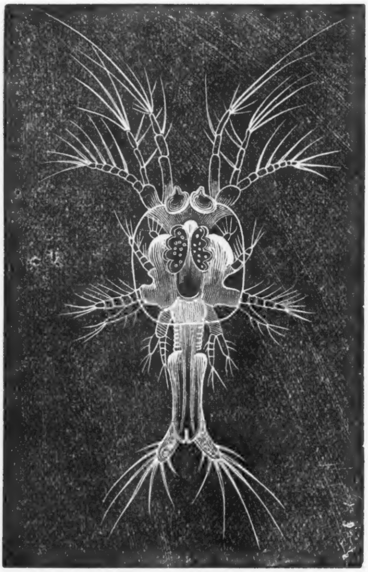
Most true Decapods, namely, the shrimps and crabs, are hatched as zoëæ (Fig. 257 after Thompson, represents the zoëa of *Carcinus mœnas*), and swim about awhile in this state, the swimming feet being the antennæ and jaws and foot jaws, which afterwards acquire a digestive function.

Now one species of the genus Alpheus, observed by the writer at Key West, is hatched in a more advanced condition; in what may be called a super-zoeal state, namely, it possesses not only five pairs of thoracic feet, but also five pairs of swimming, biramose abdominal feet, with the characteristic large claw! Here we have a sup-

pression of a true zoëal free swimming condition, just as we have seen to be the case in all the other groups of the animal kingdom, where one species may be born in an extremely imperfect condition, and another, even of the same genus, is born in a very perfect state, the intermediate phases being rapidly assumed and as rapidly discarded in the embryo.

A less extreme case is that of the lobster, which hatches without abdominal feet, but still with well developed thoracic legs. The

Fig. 256.



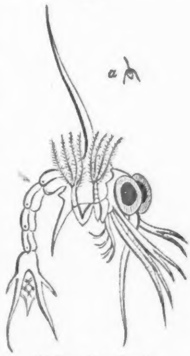
Zoëa of the same Shrimp.

larva is super-zoëal. The most extreme case, namely of an entire absence of a metamorphosis, is the cray-fish (Astacus and Cambarus), which hatches exactly in the form of the parent.

These facts are paralleled by the metamorphosis of the insects, where the terms "larva" and "pupa" are exceedingly arbitrary, the larval bee or fly attaining maturity only after a series of surprising changes, while the larval grasshopper simply differs from e adult in having no wings.

Crabs breed all through the spring and summer. At Charleston, S. C., on the 12th of April, I found the eggs of the edible crab, *Lupa hastata*, containing embryos in all stages of development from the nauplius to the zoëa. The fiddler crabs (*Gelasimus pugnax*) at Fort Macon, N. C., during the middle of May, carried eggs in which the polar cells, or formative cells of the blastoderm, were present, while others contained zoëæ, with the two claws alike, and it is probable that the strange inequality in size of the claws in these animals does not show itself until after one or more moults.

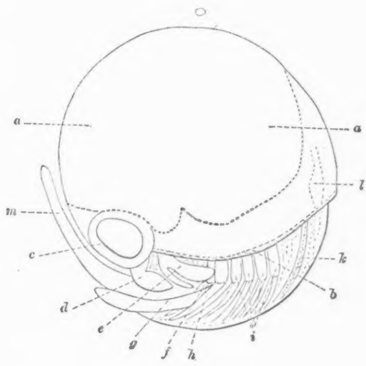
Fig. 257.



Zoëa of a Crab.

The development of the lobster has been studied with much care by Prof. S. I. Smith. The lobster breeds between April and November. Fig. 259[1] represents the embryo just before hatching. After hatching it swims

Fig. 258.



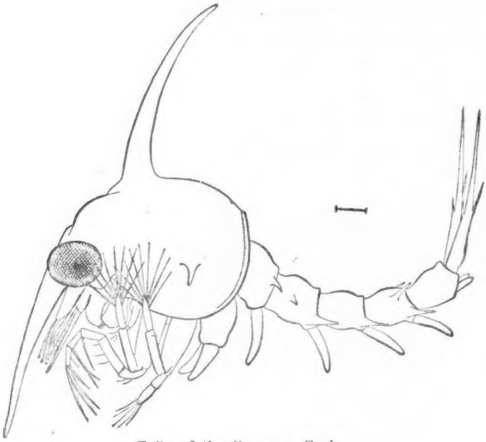
Embryo of the Lobster.

around with the thoracic feet. After moulting, the abdominal feet

[1] Fig. 258. Embryo some time before hatching, removed from the external envelope and shown in a side view, enlarged 20 diameters. *aa*, dark green yolk mass still unabsorbed; *b*, lateral margin of the carapax marked with many dendritic spots of red pigment; *c*, eye; *d*, antennula; *e*, antenna; *f*, external maxilliped; *g*, great cheliped which forms the big claw of the adult; *h*, outer swimming branch of the same; *i*, the four ambulatory legs with their exopodal branches; *k*, intestine; *l*, heart; *m*, bilobed tail seen edgewise. After Smith.

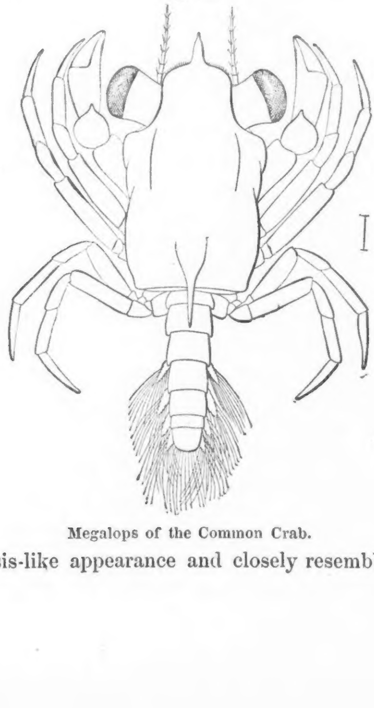
arise. After a second moult it is half an inch long and loses its

Fig. 259.



Zoëa of the Common Crab.

Fig. 260.



Megalops of the Common Crab.

formerly Mysis-like appearance and closely resembles the adult.

Soon after this it leaves the surface of the water and seeks the bottom. Specimens three inches long are quite like the adults.

Besides the zoëa stage, many crabs pass through a stage intermediate between the zoëa and adult. This is called the *Megalops* stage, as it was supposed to be an adult animal and described under this term, just as early observers mistook the Nauplius and Zoëa for adult Crustacea. Fig. 259 *a* (this and 260 after Smith) represent the zoëa of the common Crab (*Cancer irroratus*) in the last stage just before it changes to the megalops condition, and Fig. 260 the megalops of the same, magnified thirteen diameters. In two cases, *Eriphia spinifrons*, and a species of Gecarcinus, or the land crab of the West Indies, there is no metamorphosis, the young being like the adult.

Summary of the life-history of the Decapods:

1. Partial segmentation of the yolk.
2. Nauplius stage; either free swimming or undergone in the egg.
3. Zoëa stage; sometimes suppressed.
4. Megalops stage; in many crabs; in a few cases no metamorphosis.
5. Adult.

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Müller. Facts for Darwin. 1869.

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With papers by Thompson, Rathke and Claus.

II. THE INSECTS. (Tracheata.)

Under the term Insecta may be included the three groups of Myriopods, Arachnids and true six-footed insects, or Hexapoda. All differ from the Crustacea in having, as a rule, for there are exceptions among the mites, a distinct head, separate from the thorax, and in breathing by internal air-tubes (tracheæ) instead of external gills. Without spending much time in describing the metamorphoses of the winged insects, accounts of which may be found in any entomological work, we will briefly describe their embryological development, from sources less generally accessible.

Development of the Myriopods. Though Newport's classical memoir on the development of Julus will be found useful for the post-embryonic stages, the indefatigable Metschnikoff has recently cleared up the embryological development of these animals, so that we are now in possession of a life-history of these creatures, the early phases of whose existence had thus far eluded the scrutiny of embryologists.

We will now follow Metschnikoff in his studies, beginning with the history of a Polydesmus-like form, *Strongylosoma Guerinii*, an inhabitant of the island of Madeira. The eggs were laid during a period extending from February to the end of May. Before ovipositing the female buries herself in the earth one or more inches below the surface, then depositing one or two hundred eggs in the manner of several other Myriopods. The eggs are spherical, yellowish-white, and from 1 – 3 mm. in diameter.

The egg undergoes total segmentation, the process beginning in six or eight hours after it is laid, and ending on the fourth or fifth day. By this time the primitive band rests on the outside of one-half of the egg. A furrow next arises (as in the first figure of the Podurid, Isotoma) on each side of which the primitive ridges afterwards swell up. The two germ-layers now arise, the inner originating in a small mass of cells on each side of the furrow. The antennæ bud out, and subsequently three additional pairs, namely, the mandibles, the second maxillæ (the first pair wanting in the Chilognaths as in the Poduridæ) and the first pair of legs; and now the two ends of the body meet over the yolk as in the Podurids, the head touching the tail.

The brain is now formed from the outer germ-layer (ectoderm), the mouth and anal opening also being formed by an invagination of the same outer layer, the inner layer constituting ultimately the muscular walls of the digestive tract, while the epithelial lining of the large intestine also arises from the inner germ-layer.

On the fifteenth, and early on the sixteenth, day the "boring apparatus," a chitinous point by which the embryo cuts open the shell, appears on the head. The legs now assume their form, the fourth and fifth pair belonging to a single segment. The embryo now moults, the skin forming a cuticle enveloping the embryo after the shell splits asunder. The nervous cord arises from the middle portion of the upper germ-layer, though the division of the layer into an epidermal and nerve-layer has not yet taken place.

By the sixteenth, the chorion is cut through by the point of the egg-shell breaker when it splits apart, and the embryo thus remains covered by this membrane until the larva is ready to creep about, a curious fact first observed in Julus by Newport.

By the seventeenth day nine or ten true segments are formed, and the appendages begin to show articulations, while beneath the skin, the fourth, fifth and sixth pairs of feet arise as little sacs, opening in the middle line of the body. The two stigmata arise as a fine tube with a small opening on the basal end of the third pair of feet, the walls of the tube (trachea) being due to an in-pushing of the outer germ-layer. The epidermis is now well defined and the nervous cord is isolated from the skin, while on the nineteenth, or last day of embryonal life, the hairs arise over the body. The embryo would now easily be mistaken for a Podurid so remarkable is the resemblance, owing to the similar number of body-segments, and the large head, wanting in both animals the true maxillæ.

On the twentieth day the larva breaks through the membrane, and the head is clearly separated from the body. The larva closely resembles the young Julus, being as yet cylindrical, and having but nine rings besides the head.

In *Polydesmus complanatus* of the Madeira islands, the egg also undergoes total segmentation, but the embryo develops more rapidly, being by the fifth day covered w t i a membrane. Meanwhile the antennæ have appeared, and on the sixth day five additional pairs of limbs bud out, namely, the mandibles, second maxillæ (labium) and three pairs of legs. There is no shell breaker, the shell bursting, however, on the tenth day. The mandibles are very large, almost covering the labium. The larva is cylindrical, the body (the head excepted) consisting of seven segments.

Fig. 261.

Polydesmus.

The development of the singular *Polyxenus lagurus*, a little short creature with the body covered with fascicles of hairs, was observed by the Russian embryologist in Switzerland.

The egg undergoes total segmentation, but the blastoderm is restricted to one pole of the egg, being disk-like. The antennæ and mouth-parts arise as in the foregoing genera, but the three pairs of legs appear simultaneously. Metschnikoff found amœ-

boid bodies, like those in the mites, moving about in the egg, having previously separated from the blastoderm.

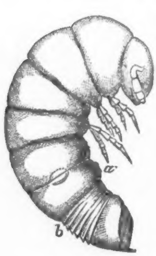
We now come to the development of the Thousand-legs (Fig. 262) which was first studied by Newport. Our skilful Russian embryologist, with all the advantage of modern means of investigation, and possibly by observing more transparent eggs than those studied by the famous English zoologist, has thrown a flood of light on the embryonic stages of a species (*Julus Morelettii*) observed by him in Madeira. The eggs were laid in November, rarely in the spring, and not at all in the summer, being deposited in rounded masses under the surface of the earth, as in the other Chilognathic myriopods. They are oval, dirty greenish white, with the shell unfortunately more opake than in the other genera mentioned. Here, also, as in the others, the segmentation was total, a thing not known to occur in the Hexapods (the Podurids excepted), and rarely in the Arachnids, chiefly in the mites. The primitive band arises on one side. There is a blastodermic moult, like that of many Crustacea, and corresponding to the "deutovum" of certain Acari. The two germ-layers were observed to arise as in the other genera, while the three cephalic appendages (antennæ, mandibles and second maxillæ) appear as in the other Myriopods.

Fig. 262.

Julus.

The shell splits, as first observed by Newport, and the retort-shaped embryo remains enveloped in the blastodermic skin, remaining connected with the chorion by a fine structureless membrane. By this time four additional pairs of limbs, like little buds, are visible under the larval skin, which is homologous with that of the Isopods. The head is free from the thorax, and the body composed of eight segments. The embryo before hatching is as in Fig. 263 (after Newport), there being no feet on the third ring from the head. This, however, is not apparently a fact of much morphological importance, as in Geophilus the embryo has a pair of feet on each body segment. In the figure, *a* indicates the rudiments of the new limbs, and *b*, the six new rings growing out from between the penultimate and last ring of the body.

Fig. 263.



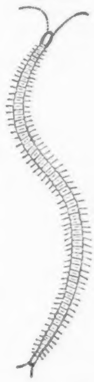
Larva of Julus.

Metschnikoff discovered in all the embryo Myriopods studied by him certain paired bodies which he names "primitive-vertebræ-like bodies." He has also noticed them in the Scorpion, the Phalangids, Araneids, Mysis and some other Crustacea, Termes and several Oligochete worms.

When we turn to the embryology of the Poduridæ we shall see how much alike those insects and the Chilognaths are in the mode of development of the embryo, and should also bear in mind the fact that the Poduras also have but a single pair of maxillæ, while Scolopendrella is half insect and half Myriopod. The conclusion that the Myriopods are a subclass of the class of insects is thus based on morphological and embryological grounds.

A later paper of Metschnikoff's gives us, for the first time, the life-history of Geophilus, one of the Centipedes or Chilopod Myriopods. He found that the yolk undergoes a total segmentation, and the primitive band surrounds one-half of the yolk. In the next stage observed the antennæ and three pairs of jaws were developed (for there are besides the mandibles, two pairs of maxillæ, like those of insects, in the Centipedes) besides twenty-three segments. The anal opening was situated in the unsegmented end of the body. In the next stage the primitive band is much longer than before, and the head and tail approach nearer to each other, while there are now from forty-four to forty-six body segments, most of them bearing rudimentary appendages, though there are none as yet on the end of the body. In a succeeding stage the head is much larger, the body longer and curved over the yolk, while the egg-shell breaker is situated on the second maxilla. In a following stage the body is still more elongated and the joints of the antennæ appear. The embryo now slips out of the split shell, the body being very long and cylindrical, not yet flattened as in maturity (Fig. 264 represents an American Geophilus), while the feet are not jointed, and resemble the ventral cirri of annelides.

Fig. 264.



Geophilus.

We see then that the Centipedes (Chilopoda) differ from the Thousand-legs (Chilognaths) in the mouth-parts being of the same number as in insects, and that the young are born with a pair of feet on each of the three segments behind the head, while the

larva is provided with nearly the full number of feet on the rest of the body, there being no metamorphosis. The body, at first cylindrical, afterwards becomes flattened. Thus the Centipedes may be said in some degree to pass through a Julus condition, and at all events, both morphologically and embryologically, the Centipede is a more highly developed creature than the Thousand-legs, a view we have always taken, but felt was rather based on *a priori* conceptions than on a sure basis of facts, now happily afforded by the beautiful researches of Metschnikoff. To sum up the phases of development of the Myriopods we have, then: —

1. Morula stage.
2. A hexapod larva (Leptus form) as in the Thousand-legs; or, as in the Centipedes, there is no metamorphosis, the young being like the parent.
3. Adult.

LITERATURE.

Newport. On the Organs of Reproduction, ana the Development of the Myriopoda. (Phil. Trans. 1841.)

Metschnikoff. Embryologie der doppelt-füssigen Myriapoden (Chilognatha). (Siebold and Kölliker's Zeitschrift. 1874.)

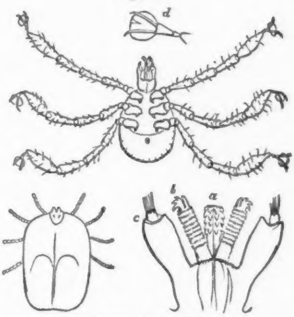
——. Embryologisches ueber Geophilus. (Siebold and Kölliker's Zeitschrift. 1875.)

Development of the Mites. Coming now to the mites and spiders, we find some peculiar features in the life-history of the former which deserve attention, though space compels us to be brief at the risk of being obscure. Most mites pass through a metamorphosis, some undergoing striking changes within the egg. For example, the *Atax Bonzi*, which is a parasite on the gills of fresh water muscles, first hatches in an oval form enveloped in a membrane (deutovum). From this "deutovum" is developed a six-footed larva. In this second larva state it is free, moving over the gills of the mussels, finally boring into the flesh of its host to undergo its next transformation. Here the young mite increases in size and becomes round. The tissues soften, the limbs are short and much larger than before, the animal assuming an embryo-like appearance, and moving about like a rounded mass in its enclosure. After a moult it assumes the so-called "pupa-state." During this process the limbs grow much shorter and are folded beneath the body, the animal being immovable, while the whole body assumes a broadly ovate form, and looks like an embryo just before hatching, but still lying within the egg.

In the genus Myobia, a parasite of the European field-mouse,

there is not only a "deutovum," but also what Claparède calls a "tritovum-stage," there being two stages with distinct embryonal membranes before the six-legged free larval state is assumed, the larva when hatching having thrown off two membranes, as well as the egg-shell. Certain bird-mites pass through four stages to reach the male condition, while the females pass through as many as five before attaining sexual maturity. Fig. 265 illustrates the six-legged larva of the tick, which is simply a large mite. The eggs of the mites either undergo total segmentation or a partial one, as in the spiders.

Fig. 265.



Tick and Six-legged Young.

The water-bears or Tardigrades are born with four pairs of legs, not undergoing any metamorphosis. Not so, however, with certain worm-like mites, which by their parasitic life lose all resemblance to other mites and are often mistaken for intestinal worms. I refer to the Pentastoma and Linguatula. Here the metamorphosis is backwards, the young after passing through a morula condition, being born as short, plump, oval mites, provided with boring horny jaws, but with only two short rudimentary legs.

Finally, we come to those problematical forms, the sea-spiders, or Pycnogonidæ, which are often referred to the Crustacea, whose development has been so faithfully studied by Dr. Dohrn. The yolk undergoes total segmentation, and the young are hatched with three pairs of legs, which after moulting attain in some species an extraordinary length.

To sum up, then, certain mites pass through either—

1. A Morula state, or the yolk only partially divides.
2. Sometimes one or two embryonal stages (deutovum and tritovum).
3. A six-legged larval state.
4. Eight-legged "pupal" state.
5. Adult.

LITERATURE.

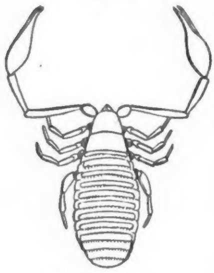
Claparède. Studien an Acariden. (Siebold and Kölliker's Zeitschrift. 1868.)
Leuckart. Bau und Entwickelungsgeschichte der Pentastomen. Leipzig und Heidelburg. 1860.

Dohrn. Untersuchungen ueber Bau und Entwicklung der Arthropoden. Heft. I. 1870.

Consult also papers by Dugès, Doyère, Müller, Van Beneden, Robin and others.

Development of the False-scorpions (Fig. 266). Some most unexpected features occur in the life-history of these little tailless scorpion-like creatures, which are found living under the bark of trees, and under stones, etc. The female runs about in early summer pressing the eggs to the under side of its body by means of its claws or nippers.

Fig. 266.



False-scorpion.

Here, as in most mites, the segmentation of the yolk is total. The blastoderm forms, and then a singular feature ensues, namely, the collection of an albuminous substance between the egg-shell and the blastoderm, increasing the size of the egg very materially and containing small bodies; suggesting an embryonal membrane, though Metschnikoff does not regard it as truly such. Soon the blastoderm becomes two-layered.

Next arise the rudiments of the two large claws, before any other limbs appear; at the same time a huge projection forms on the head, with indications of muscular bands. This strange appearance is merely a sort of temporary upper lip. At this time the end of the body is conical and curved beneath the abdomen. In this imperfect stage the embryo sheds a skin and then breaks through the delicate egg-membrane, becoming free, though the larva, kangaroo-like, is still attached to the under side of the mother Chelifer, where it remains until it has completed its metamorphoses, though of course it derives no nourishment from its mother.

Now the embryo-larva is nearly as long as broad, with the singular hood-like upper lip, and the rudiments of the first pair of feet directly behind the enormous rudimentary nippers. Within are no signs of a digestive sac or any other organs, simply a mass of yolk cells.

In the second larva-state the body is broader than long, the "upper lip" diminutive in size, and the mandibles and four pairs of legs are present. Here also, as in the scorpions and the spiders, four pairs of deciduous abdominal feet appear (such as our author has also seen in Phalangium and Forficula). There are now seven segments in the abdomen.

The larval skin is after a while ruptured, and the insect deserts its parent, in a form like that of the mature animal.

It will thus be seen that the first larva of Chelifer is comparable with that of certain low mites, but very different from the Scorpion, its nearest ally, the segmentation of the yolk being total, as in most mites, the sea spiders, Pentastoma and the Tardigrades, while the larval condition is on a still lower plane of existence than the Nauplius of the lower Crustacea. The false-scorpion differs much more from the spiders, the scorpion and other Pedipalps, than the harvest-man (Phalangium) Phrynus and the Acarina.

The harvest-men, or daddy-long-legs, as the researches of Metschnikoff and Balbiani show, develop as in the spiders, differing from them only in the want of a provisional post-abdomen and the relatively smaller abdomen.

The false-scorpions pass through, then:

1. A Morula stage.
2. Hatching in the first larval state, with but one pair of appendages (maxillæ).
3. Second larval state, with all the limbs present, but enveloped in a larval skin.
4. Throwing off the larval skin, becoming free and with the form of the adult animal.

LITERATURE.

Metschnikoff. Entwicklungsgeschichte des Chelifer. Siebold and Kölliker's Zeitschrift für wissens. Zoologie. Leipzig, 1871.)

Development of the Scorpions, etc. (Pedipalps). In a beautiful memoir by Metschnikoff on the embryology of the Scorpion we have full details regarding the embryonic life of this animal, which brings forth its young alive early in summer; being one of the very few viviparous insects known. His studies were made on three species of Scorpio found in southern Europe. The females are big with young at the end of spring or early in summer. I have observed this to be the case with the scorpion of the Florida Keys.

The earliest phases of development take place in the follicles of the ovary. The blastoderm is formed out of a few polar cells just as in the higher crustacea (Isopods and Decapods). It is at first a round disc, which eventually splits into two germ-layers. Soon

it becomes oval, the larger end being the head-end. The next step is the formation of a primitive longitudinal furrow, and afterwards of two transverse creases dividing the germ into three portions, the anterior the head, the middle portion the thorax and abdomen, and the third, the so-called post-abdomen.

The egg now leaves the follicle and descends into the oviduct. The head grows broader, and by this time the germ is subdivided into twelve segments, from which the appendages next bud out. The mouth may be discerned, the claws are indicated, the post-abdomen is folded on the body and the nerve-ganglia may be detected arising from the outer germ-layer. The embryo is now surrounded by a membrane composed of two layers of quite dissimilar cells.

A singular feature, also noticeable in other Insecta, is the presence of six pairs of deciduous abdominal feet, which directly assume the form of horizontal plates, with a terminal button, which finally disappear, the four pairs of stigmata taking their place; the second pair, however, become converted into the comb-like tracheal gills, so that it is evident that these are exvaginate stigmata. The germ (primitive band) is now broader, and the limbs have a more definite outline and are jointed, while the head is narrower than before, assuming the shape of that of the adult.

Metschnikoff claims that there are three germ-layers in the Scorpion, homologous with those of the vertebrates.

A summary of the chief events in the development of the scorpion is as follows:

1. Partial segmentation of the yolk, the embryo developing within the oviduct.
2. The young is brought forth by the mother, in a form exactly like the adult, and about half an inch long, about a dozen being produced in a season.

LITERATURE.

Rathke. Zur Morphologie. Reisebemerkungen aus Taurien. 1837.
Metschnikoff. Embryologie des Scorpions. (Siebold and Kölliker's Zeitschrift. 1870.)

Development of the Spider. From the life-history of one spider we may learn that of all, as there is much uniformity in the mode of development of all those species whose growth has been yet observed. The eggs are laid usually in silken cocoons. All undergo partial segmentation of the yolk, which is surrounded by

a blastoderm, which thickens on one side forming the primitive band, eventually becoming marked off into rings or zones, as in

Fig. 267.

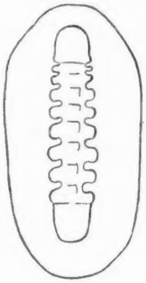


Fig. 268.

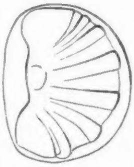
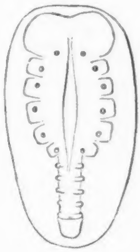


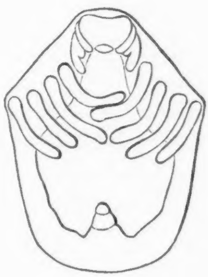
Fig. 269.



Development of the Spider. After Claparède.

Fig. 267. The primitive band elongates, new segments appear, (Fig. 268) until finally the germ appears when drawn as if spread out, as in Fig. 269. Besides the rudiments of the two pairs of head-appendages (*i.e.*, the mandibles and maxillæ) and the four pairs of legs, there are at first four, as in the figure, and subsequently six pairs of deciduous abdominal feet as in the Scorpion and two other species of tracheate insects.

Fig. 270.



Advanced embryo of the Spider.

Soon the mouth-parts and legs grow longer, and the embryo spider lies on the surface of the yolk as seen in Fig. 270. Finally, the head, originally distinct from the thorax, becomes soldered to the thorax; the eyes appear and the animal is rapidly perfected, the spider being hatched in a form like the adult, differing only in size and its paleness of color; the changes in after life being almost imperceptible. All spiders, then, so far as known:

1. Undergo in the egg state a partial segmentation of the yolk, and
2. Are hatched in the adult form, having no metamorphosis.

LITERATURE.

Herold. De Generatione Aranearum in Ovo. Marburg, 1824.
Claparède. Recherches sur l'Evolution des Araignées. Utrecht, 1862.

Development of the true Insect. While the history of the winged insects before hatching is much the same in the different orders, there are some exceptional modes of development possessing a high degree of interest on account of the resemblance to the mode of embryonic growth of still lower animals. First I will give an epitome of the changes observed by myself within the egg of a

Fig. 271.

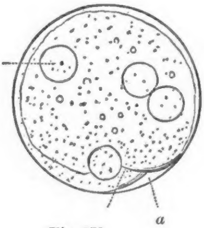


Fig. 272.

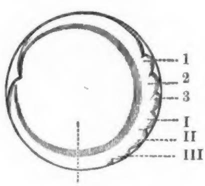


Fig. 273.

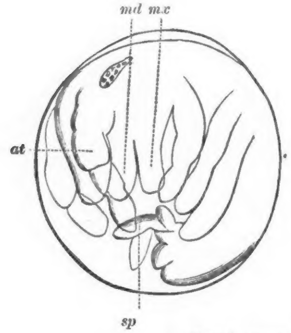
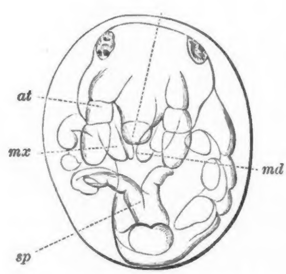


Fig. 274.

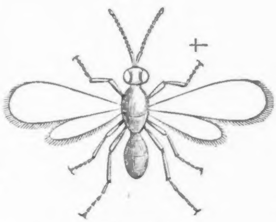


Development of a Poduran.

Poduran. The eggs were not studied until after the formation of the blastoderm, but Ulianin of Moscow has ascertained that the eggs of certain Podurids undergo total segmentation, in this feature, as indeed in some of the other phases of embryonic life, closely resembling the Myriopods. Fig. 271 shows the primitive band infolded at a, as in the Myriopod germ. A more advanced stage (Fig. 272) shows the rudimentary appendages (1–3, I–III) the

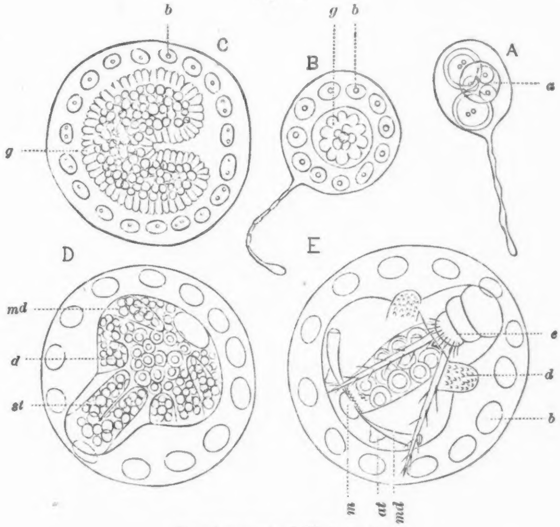
second maxillæ or labium, not being present. (It will be remembered that a pair of maxillæ are also wanting in the Thousand-legs.) The next change is the closure of the body-walls over the yolk, and the appearance of the rudiments of the "spring." By this time the serous membrane is formed, being a tough membrane enveloping the germ. In a succeeding stage the intestine is formed and the rudiments of the antennæ and legs have greatly increased in size. Still later, the appendages begin to show traces of joints. In a later period (Fig. 273, 274 *a*) the head is quite

Fig. 275.



Platygaster.

Fig. 276.



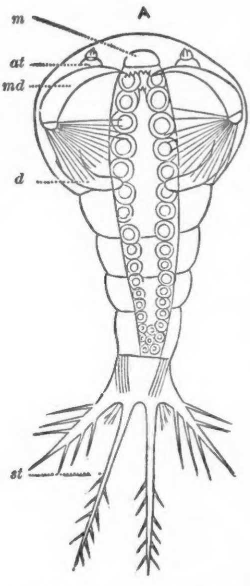
Development of Platygaster.

separate from the rest of the body, the antennæ (*at*) are of much the same shape as in the larva, while the upper lip (labrum) and clypeus are clearly indicated, and the spring (*sp*) is fully formed. Soon after, the "finishing touches" are, as it were, put on, and the mandibles and maxillæ (*md* and *mx*) are withdrawn within the

head, when the embryo throws off the chorion and serous membrane and runs about in a lively way.

Coming now to the true winged insects, we are met with a very exceptionable mode of development, observed by Ganin in certain species of minute ichneumon flies, some of them egg-parasites. The ovary of Platygaster (Fig. 275) differs from that of most other insects in that it is a closed tube or sac. Hence it follows that at every time an egg is laid, the egg-tube is ruptured. The egg is a single cell. Out of this cell (Fig. 276 *A*, *a*, arise two other cells, but the central cell (*a*) gives rise to the embryo, which as seen at *B*, *g*, originates from the nucleus of *A*, *a*, while the circle of cells, *b*, form an equivalent to the serous membrane or blastodermic skin of other insects and crustacea. The germ farther advanced, as in *C*, *g*, reminds us of the embryo of certain low worms. *D* and *E* are successive stages in the growth of the provisional larva (Fig. 277, *m*, mouth; *at*, antennæ; *md*, mandibles; *d*, deciduous organs). In this condition it clings to the inside of its host by means of its temporary hook-like jaws (*md*), moving about like a Cestodes embryo. The nerves, blood vessels and air tubes are wanting, while the alimentary canal is simply a blind sac, remaining in an unorganized state.

Fig. 277.



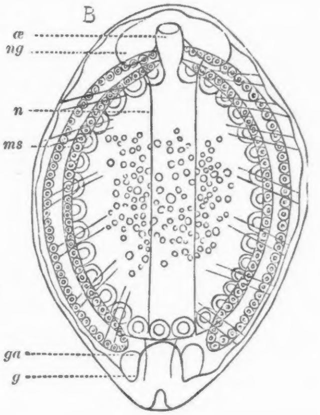
First larva of Platygaster.

It then passes into the second larval state (Fig. 278) like that of the ichneumon flies, and the remaining changes into the pupal and winged state are as usual.

In Polynema, the larva in its first stage is very small and motionless, and with scarcely a trace of organization, being a mere flask-shaped sac of cells. After five or six days it passes into a worm-like stage, and subsequently into a third stage (Fig. 279, *tg*, three pairs of abdominal tubercles destined to form the ovipositer; *l*, rudiments of the legs; *fk*, portion of the fatty body; *at*, rudi-

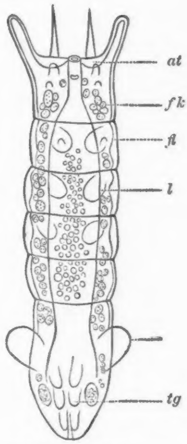
ments of the antennæ; *fl*, imaginal disks or rudiments of the wings).

Fig. 278.



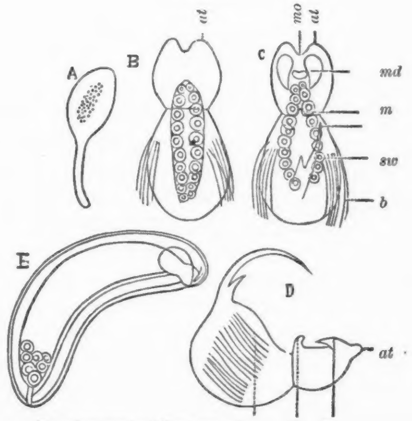
Second larva of Platygaster.

Fig. 279.



Third larva of Polynema.

Fig. 280.



Development of Egg-parasites.

The larva of Ophioneurus is at first of the form indicated by Fig. 280, *E*. It differs from those genera already mentioned, in

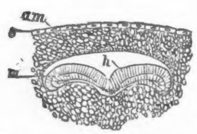
remaining within its egg-membrane, and not assuming their strange forms. From the non-segmented, sac-like larva it passes directly into the pupa state.

The development of Teleas is like that of Platygaster. Fig. 280, *A*, represents the egg; *B*, *C* and *D*, the first stage of the larva, the abdomen being furnished with a series of bristles on each side. *B* represents a ventral, *C* a dorsal, and *D* a profile view; *at*, antennæ; *md*, mandibles; *mo*, mouth; *b*, bristles; *m*, intestine; *sw* the tail, and *ul* the under lip or labium. Not until the beginning of the second larval stage is the primitive band formed.

In all the other insects whose early stages have been studied, there is a remarkable uniformity, all travelling nearly the same developmental road until just before hatching, when they assume the characteristics belonging to the larval forms of their respective orders. For example not until very late in embryonic life do the germs of a bee, a bug, a beetle or a fly, or even a dragon fly, differ in any essential point.

We will, then, give a general and brief account of the mode of growth of the germ, not dwelling on the metamorphoses of insects. The egg after fertilization shows the first sign of the new life thus originated by the appearance of a few polar cells; these multiply and surround the egg with a single layer, thus forming the blastoderm. The segmentation of the yolk is thus peripheral and partial. On one side of the egg the blastodermic cells elongate, forming a thickening, called the primitive streak or band, which in some insects sinks into the yolk. By this time the serous membrane (*s*) has moulted and envelopes the germ and yolk. The germ soon splits into an outer (ectoderm) and inner layer (endoderm) and then sheds the true amnion, which as in vertebrates, peals off from the primitive band or germ, and acts as a protective membrane.

Fig. 281.

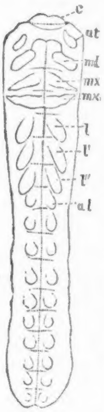


Section of Sphinx Embryo.

In Fig. 281 (after Kowalevsky) representing a transverse section of the embryo of a Sphinx, we see the relation of parts. The primitive band has sunk into the yolk which is surrounded by the serous membrane (*s*) or blastodermic skin (formerly, but erroneously termed the amnion). The primitive band is seen to be formed of two layers, *h*, the outer, and *m*, the inner. In the

outer is subsequently formed the nervous cord and air vessels, while from the inner arise the digestive canal and its glands and the organs of circulation. The amnion (*am*) envelopes the germ. From the ventral side of the primitive band bud forth the appendages of the head, the thorax, and as in the embryo caterpillar, the ten pairs of abdominal legs, *i.e.*, one to each ring, a portion of which disappear before it hatches, no caterpillar having more than five pairs of prop-legs. Fig. 282 (after Kowalevsky) represents the primitive band of the Sphinx, with the four pairs of head appendages (*c*, upper lip; *at*, antennæ; *md*, mandibles; *mx*, *mx'* first and second maxillæ), and the three pairs of thoracic legs (l, l' l'') succeeded by the ten pairs of abdominal legs. The observer will notice that all the appendages, whether of the head or thorax or hind-body, are alike at first, being simple outgrowths of the outer germ-layer.

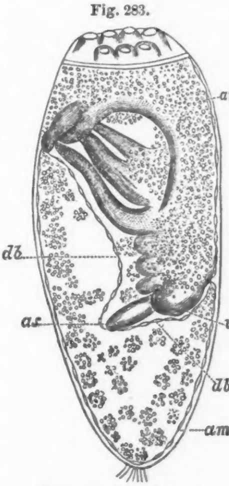
Fig. 282.



Sphinx embryo.

When in a more advanced stage, as seen in the accompanying figure (283, *am*, serous membrane; *db*, amnion; *vk*, forehead) of the embryo louse, the antennæ are longer than the mouth-parts, and the legs are still larger. After this those features characterizing the different orders of insects appear, and shortly before hatching we can ascertain to what group the embryo belongs.

Fig. 283.



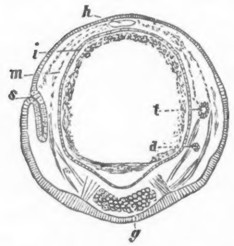
Embryo of the Louse.

As regards the development of the internal organs, the nervous system is the first to show itself, the alimentary canal is next formed, and the stigmata and air-tubes arise as invaginations of the outer germ-layer. The development of the salivary glands precedes that of the urinary tubes, which, with the genital glands are offshoots of the primitive digestive tract. Finally the dorsal vessel is formed. Fig. 284 (after Kowalevsky) is a transverse section of the embryo bee; *g*, is the nerve ganglia; *i*, the alimentary canal; *m*, muscular bands running to the heart (*h*);

d is a gland, and *t*, indicates the trachea, its mode of origin being illustrated on the left side of the figure where it is seen in communication with a stigma or air-hole (*s*).

So far as we know (the Thysanura and certain minute ichneumons excepted) there is in the winged insects a remarkable uniformity in their mode of development, and it is difficult to determine what embryological characters may be set down as distinguishing even the different orders, but they will probably be found, if anywhere in the form of the advanced embryos.

Fig. 284.



Section of advanced Sphinx embryo.

A summary of the most important events in the life-history of insects is as follows:

1. Peripheral (partial) segmentation of the yolk (in the Poduræ a true Morula condition).

2. Larva hatched in the form of the adult, but (in Aphis and Miastor producing young alive) wingless, and undergoing an incomplete or complete metamorphosis.

3. Pupa state, more or less marked (in one species of Chironomus producing young).

4. Adult, usually winged, sometimes propagating asexually.

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REVIEWS AND BOOK NOTICES.

TENNEY'S ELEMENTS OF ZOOLOGY.*—This is a profusely illustrated book, of convenient size and well adapted by its simple style for instruction in schools. It is a decided improvement in matter and illustration on the "Manual of Zoology" by the same author, as more attention is bestowed to anatomy and histology; this portion being illustrated by well selected engravings, mostly taken from Milne-Edward's "Zoology."

MICROSCOPY.

THE "REFLEX ILLUMINATOR" FOR DIRECT ILLUMINATION.— Mr. Samuel Wells, of Boston, communicates to the "Cincinnati Medical News," his experience with Mr. Wenham's last illuminator, used upon transparent objects with transmitted light. Of course to obtain the direct effect the object must be mounted in balsam or other highly refractive medium, and the illuminator connected with the slide with glycerine or otherwise. The lens must be an immersion, and over 82° of working angular aperture, since nothing under 41° of semi-aperture can be lighted by this arrangement. Mr. Wells, among a large number of lenses, found only four capable of working with light at this angle,—a Powell & Lealand $\frac{1}{16}$, Tolles' $\frac{1}{10}$, and Tolles' four system $\frac{1}{6}$ and $\frac{1}{10}$. All these are famous resolving lenses, and their performance with this light is described as remarkably beautiful. An exactly similar use of the Wenham Paraboloid has been a favorite method of high-power illumination (differing only in angle and in not being limited to an unilateral effect) and gives the same exquisite definition with a perfectly corrected objective, though failing entirely with many objectives that are called first class.

RELIABILITY OF THE MICROSCOPE.—Mr. John Michels paper in "Popular Science Monthly," on the Microscope and its Misinterpretations, mainly by virtue of its title, largely contributes to an exaggerated popular estimate of the general untruthfulness of microscope teachings. The paper itself is a good popular synopsis of the Podura scale controversy, but has about the same rela-

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*Elements of Zoology. A Text Book. By Prof. Sanborn Tenney. Illustrated by 750 wood engravings. New York: Scribner, Armstrong & Co. 1875.

tion to the general credibility of microscopical science that a dispute about some confessedly difficult double star would have to the science of astronomy. Experience is suggested as a safeguard, and so are high powers, which are of undisputed value notwithstanding that they chiefly, if not only, are liable to serious danger of misinterpretation. The necessity of corroboration of results in important cases by different observers is urged, to which the editor of the "Technologist" adds that varied methods of preparation are a stronger confirmation than a number of observers.

A CONCENTRATED METHOD OF MOUNTING.—Mr. C. H. Robinson, of Cleaveland, contributes to the "Postal Micro-cabinet Club," a slide illustrating a method of mounting where the space under a single large cover-glass is occupied by a considerable number of small circles with an object in each. He makes the circles of white zinc varnish, and sometimes adds a circle to the edge of the cover-glass as a finish. This method of mounting, the appearance of which is decidedly handsome, is particularly applicable to displaying several varieties of one species (as of selected diatoms or of foraminifera) on one slide, or to presenting in contrast different methods of preparing the same species.

NOTES.

WE noticed, in our last, that an Ohio State Association of Archæologists had been formed, and we now have to record the organization of similar State Associations in Indiana and Tennessee. These State Associations will be of great benefit if they result in the establishment of permanent museums of Archæology at the several capitals and foster careful research. It is also greatly to be hoped that they will take action at once in relation to the preservation of some of the most important of the ancient earthworks of the west and south.

IMPORTANT ANNOUNCEMENT!

Arrangements have been made by which Messrs. H. O. Houghton & Co., will become the publishers of the *American Naturalist*, beginning with Vol. X, 1876. Farther announcements will be made in our next number. Subscriptions for Volume X should accordingly be sent to H. O. Houghton & Co., Boston, Mass.